THE ROLE OF TECHNOLOGY IN THE DEVELOPMENT OF GEOTHERMAL ENERGY

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Madame Chairman and Members of the Subcommittee. Thank you for the opportunity to be before you today to discuss the role of technology in the development and utilization of our nation's geothermal resources. My name is Bob Lawrence, and I am President of Bob Lawrence and Associates, a firm that has worked with the geothermal industry for over 17 years. I am also a member of the Board of Directors of the Geothermal Energy Association, the trade association for the US geothermal industry, whose staff has helped research the statement presented to the Subcommittee today.

Geothermal resources are a potentially vast supply of energy for the United States. According to the United States Geological Survey, there are some 127,000 megawatts (MW) of "undiscovered" geothermal resources in the United States. Currently, geothermal resources produce more than 2,600 MW of power throughout California, Nevada, Hawaii and Utah. Geothermal energy can be used to make electricity or for direct uses such as space heating, aquaculture, and industrial processes. As a source of electric power, geothermal plants provide dependable baseload supply at a stable cost that is not subject to dramatic price fluctuations. Geothermal energy is a clean, renewable energy source that ranks among the best power production alternatives for low emissions of greenhouse gases.

Geothermal electric generation, at 16 Billion Kw-hrs per year, is the largest contributor to delivered electricity from Renewables except for Hydro generation. Cost-shared Department of Energy investments in geothermal energy R&D, starting in the 1970s, have made possible the establishment of the geothermal industry in the United States. Today the total, retail value of this electricity exceeds $1 Billion per year. The Industry:

- **returns over $41 million annually** to the Treasury in royalty and production payments for geothermal development on Federal lands;

- **supplies the total electric-power needs of about four million people in the U.S.**, including over 7 percent of the electricity in California, about 10 percent of the power in Northern Nevada, and about 25 percent of the electricity for the Island of Hawaii (the Big Island);

- **employs some 30,000 U.S. workers**;

- **uses over $500M worth of steel structures;**

- **displaces emissions** of at least 16 million tons of carbon dioxide, 20 thousand tons of sulfur dioxide, 41 thousand tons of nitrogen oxides, and 1300 tons of particulate matter every year, compared with production of the same amount of electricity from a State-of-the-Art coal-fired plant; and
- **has installed geothermal projects worth $3.0 billion overseas**, mostly in the Philippines and Indonesia.

We are often asked the question: "Why do you need technology development? Can't you simply use the exploration and extraction technology that is used in the oil and gas industry?" In fact, the opposite has proven true. Geothermal energy exploration, development, extraction and operation are far more technologically challenging than oil and gas extraction, and the oil and gas industry has benefited greatly from geothermal technology advances. Oil and gas generally occur in layers of sediments in the earth, which are generally horizontal and uniform in their structure. Geothermal energy, on the other hand, occurs in volcanic regions where cracks have occurred in the earth's crust, and molten lava, or magma, has come close to the earth's surface. Water then penetrates the region, providing pockets of superheated water and steam which are the geothermal resource. Under the surface, the region would be best described as a "jumble" of extremely hard rock like granite and obsidian, fractures running in many different directions, and pockets of geothermal resource which may, or may not, be interconnected. This is, clearly, a much harder challenge to develop than oil and gas.

In addition, the production hole that needs to be drilled for oil and gas can be as small as four inches, whereas a geothermal production well requires a diameter of at least 12-3/4 inches. Whereas an oil and/or gas well is drilled in softer, sedimentary structures, the drilling for geothermal resources takes place in some of the most complex geologic structures in existence, with the earth's hardest rocks. This is why the advances in geothermal drilling technology, over the years, have been so important to the development and utilization of this extremely important renewable resource.

Resource Basics

Most high-temperature geothermal resources occur where magma (molten rock) has penetrated the upper crust of the Earth. The magma heats the surrounding rock, and when the rock is permeable enough to allow the circulation of water, the resulting hot water or steam is referred to as a hydrothermal resource. If the hot fluids are confined at pressure, the resource becomes a hydrothermal reservoir, analogous to an oil or gas reservoir. Such reservoirs are used today for the commercial production of geothermal energy. They benefit from continuous recharge of energy as heat flows into the reservoir from greater depths.

However, most of the geothermal resource lacks sufficient water and/or permeability to enable the economic production of energy. At present, only high-grade (shallow, hot, and permeable) hydrothermal reservoirs are economic for the generation of electricity. The potential for advanced technology to expand the economically available geothermal resource base is enormous. With continued advances, geothermal resources could expand beyond the western states to provide reliable power and energy to perhaps many additional states, as shown in the figures below.

Figure 1 displays a heat flow map prepared by researchers at Southern Methodist University for the Department of Energy. It shows the expected heat in the earth at a depth of 6 kilometers (19,685 feet), and indicates that at this depth the temperature of the rock is over 100 degrees C throughout all of the United States. Existing geothermal power technology can produce electricity from resources at temperatures as low as 90 degrees C.

Reaching these depths is not impossible. Oil and gas drilling technology has allowed successful drilling to depths of 6 km and more. The drilling depth record for the Gulf of Mexico was 33,200 feet in January 2004 (Shell Oil.) Also, you need more than heat. Conventional geopressurized resources require an intersection of underground heat, water and fractured rock, which this map does not show.

However, producing geothermal power from such deep resources is uneconomic given today's available technology. The Department of Energy's Enhanced Geothermal Systems program seeks to develop the technology to engineer geothermal systems where natural conditions do not exist and expand the economically recoverable resource to depths approaching oil and gas.

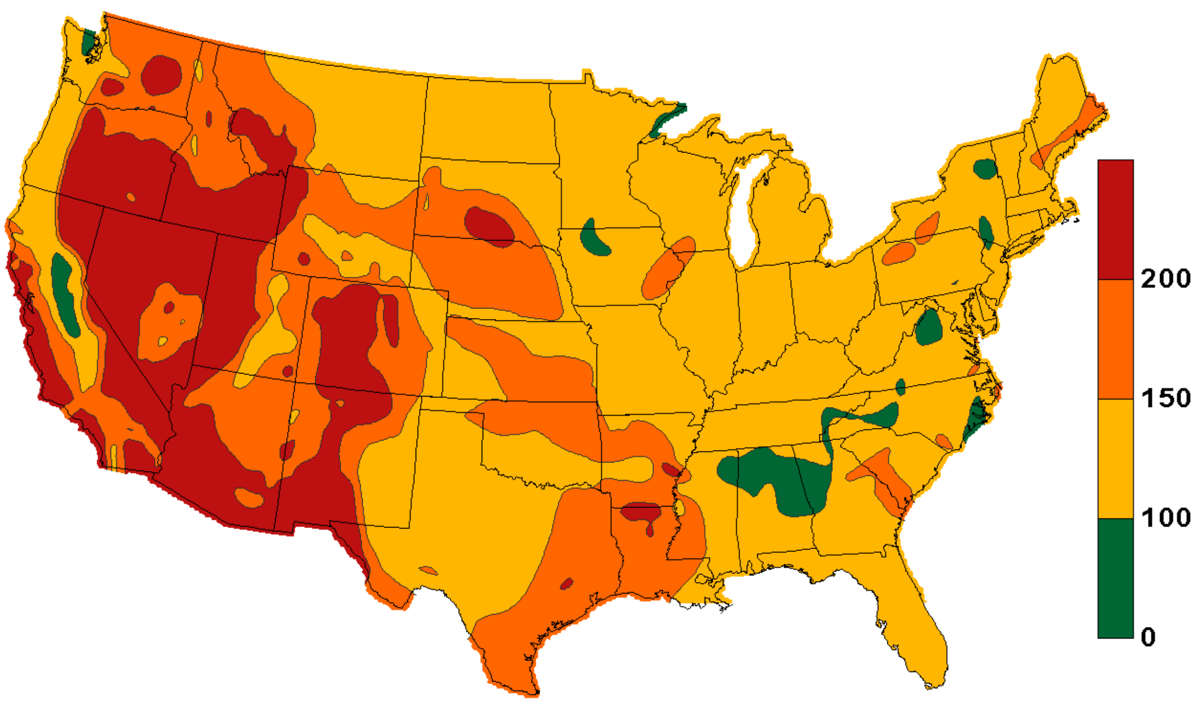

Figure 1: Estimated Earth Temperatures (°C) at 6 km Depth

Technology Basics

Geothermal projects are capital-intensive, and the major expenses are incurred before the project produces revenue. Exploration, while not expensive relative to total project costs, still has a high degree of risk which can influence investment decisions. The most expensive element of a power generation project is surface plant construction, followed by drilling to create a well field.

Typically, geothermal power plants are baseload facilities, but they may be operated intermittently in a load-following mode. The plants have very high availabilities and capacity factors, often exceeding 90 percent. Liquids produced from the reservoir are reinjected to sustain reservoir pressures and to prevent contamination of ground and surface water. After mitigation, air emissions are minimal, and binary plants that use a secondary working fluid and dry cooling usually have almost zero emissions.

For cases in which reservoir flow rates are inadequate due to low permeability or lack of fluids, reservoirs may be engineered to increase productivity. Such engineered reservoirs are called Enhanced Geothermal Systems (EGS). Much EGS technology is still in the experimental stages, but a number of countries are pursuing this technology because of its potential to tap the large resources contained within geothermal resources of low permeability.

Industry Basics

The U.S. geothermal power industry, which took off in the early 1970s, underwent a boom in the late 1970s and 1980s that was followed by a period of consolidation in the 1990s. The industry, once dominated by large oil companies and utilities, is now made up of small to mid-sized independent power producers. During the 1990s industry focused on international markets, and only minimal new domestic development occurred. Since 2000, industry has shown renewed interest in domestic development thanks to reduced production costs, an improved competitive position due to increased prices for power generation from fossil fuels, and incentives such as state renewable portfolio standards. New projects totaling about 400 MWe have been announced.

Domestic geothermal energy production is currently a $1 billion a year industry that accounts for almost 20 percent of all non-hydropower renewable electricity production, and about 0.35 percent of total U.S. electricity production. Installed nameplate geothermal electricity generating capacity in the U.S. has grown from about 500 MWe in 1973 to over 2,600 MWe today.

Some examples of technological advances:

Engineering Geothermal Systems:

The Geysers Recycled Water Project

Recent technological advances have enabled geothermal developers to boost energy production at existing geothermal fields while providing a means for nearby communities to properly dispose of treated wastewater. Pioneered in Lake County, California in 1997, and most recently used by Calpine Corporation at the world's largest geothermal field known as "The Geysers," the wastewater reinjection system has been an astounding success. The project allows geothermal developers to inject large amounts of reclaimed wastewater from nearby towns into the geothermal reservoir to recharge it thereby boosting their energy production. The project also provides communities a safe and effective way of disposing of treated effluent which would otherwise be discharged into nearby waterways.

The project at The Geysers is being hailed as a unique solution to Santa Rosa, California's problem with disposal of reclaimed wastewater. Historically, the city disposed of highly treated effluent directly into the Russian River, a situation which threatened the river's well-being and prompted state water quality regulators to order Santa Rosa to find an alternative to the river. The project is also a boon to the sustainability of The Geysers geothermal fields. Since production peaked in 1987, The Geysers energy production has slowly declined. It is hoped that the wastewater reinjection project will boost energy production by 85 megawatts and maintain a sustainable level of production at The Geysers over the long-term. It is important to note that agriculture is an important component of this project. Sonoma County is a well known viniculture region and makes some of the best wines in the world. This project includes take off locations for agriculture use so that their water withdrawals from the Russian River do not impact steelhead, a federally listed species.

Mineral Recovery:

Aside from producing electricity for millions of American homes, geothermal energy producers now have the ability to extract valuable mineral resources from hot geothermal brines. Use of brine as a metal source eliminates the need for some underground or surface mining that might have more severe environmental impacts. Currently, CalEnergy's geothermal plants at the Salton Sea in California are collecting zinc in this environmentally friendly manner. At the company's plants, high-temperature, highly-saline brines from the deep geothermal reservoir are brought to the surface and "flashed" in pressure vessels to produce steam to drive a turbine and generate electricity. Before the brines are pumped back underground, zinc is recovered via ion exchange, solvent extraction and electrowinning. The resulting metal is a valuable commodity used in many industries, including storage battery and galvanized steel production. CalEnergy is currently testing similar technology to extract manganese and other valuable metals as the brines, which can be up to one-quarter solids, are rich in metals including rare metals.

Exploration

Drilling exploration wells to prove a geothermal resource is a major investment which occurs early in the life of a project, with very uncertain outcome. Thus, there is great value in using geoscientific methods to reduce the risk of dry holes. The most effective of these methods include geochemical analysis of surface thermal features, surface geophysical surveys (especially those that provide deep soundings of electrical conductivity, such as magnetotellurics), and drilling of relatively shallow, slim holes to measure temperatures. Some recent improvements include the following:

- Advanced sampling and analysis methods for geothermal gases, including the noble gases.
- Commercially available magnetotelluric surveys using modern lightweight equipment and multiple simultaneous station set-ups, thereby lowering per-station costs and speeding up coverage.
- Practical 3D modeling of magnetotelluric data to develop realistic conceptual resource models that can be tested by drilling.
- Extension of slim-hole drilling technology to greater depth, allowing evaluation of reservoir properties.

In addition, the improvements in geothermal drilling technology (described below) can be applied to lower the cost and increase the effectiveness of exploration drilling.

Advanced Drilling:

We are fortunate that much of the R&D done in oil and gas drilling has a waterfall effect to geothermal. Many of the improvements in drill bit and cementing technologies have come from the oil and gas industry as they drill deeper and hotter resources. Lost circulation while drilling continues to be one problem that geothermal research is focused on as it causes lost time and money in many of the geothermal regimes that are drilled.

A current demonstration project highlights a new technology for protecting shallow casing (< 500 feet depth) from shear deformation due to landslides. The approach incorporates the overdrilling of casing on an existing geothermal well using specially designed drill bits up to 56 inches in diameter. Successful implementation of this technique will preserve production from the well and demonstrate a practical method for repairing and/or modifying shallow casing strings by protecting them from ground movement.

Advanced Power Systems:

New steam paths were installed at five power plants from 1999 through 2002. The design strategy was to reduce the steam turbine inlet capacity by 30% to effectively raise the turbine inlet pressure to provide more available energy to the turbine.
Benefits realized included generation gains at the plants with a decrease in steam flow rate. A secondary benefit was realized at adjacent plants as additional steam was then available to them.

Modified steam paths were installed at 3 separate power plants in 1999, 2000 and 2001. This design strategy was also to reduce the swallowing capacities by about 30% along with installation of shorter turbine blades coupled with matching restrictions in the diaphragm blocks made to the first three stages of the steam paths. Benefits were seen at the plants that received the new equipment as well as adjacent plants.

An example of a highly successful R&D program can be seen at the Geysers. Power plant availability was roughly 62% prior to the development of the steam wash process. In the years following the implementation of this technology, the plant availability jumped to roughly 92%, nearly a 50% increase. Over a billion dollars in extra electrical generation have been recovered since the technology was introduced.

There are many promising technologies that are being developed or can be developed with adequate R&D funding that can advance geothermal energy generation.

Environmental Emissions Reductions/Mitigation:

Since the beginning of the geothermal development in the United States, the industry has come a long way in emissions reductions and mitigation. It is important to keep in mind that all forms of power generation have environmental impacts; however, if you compared each from cradle to grave you would learn that geothermal comes out cleaner than even other renewable energy resources. Although geothermal plants produce few, if any, air emissions, some pollutants can be of concern to geothermal developers. Air emissions such as nitrogen dioxides, carbon dioxides, carbon monoxides, particulate matter and ozone are typically only emitted from geothermal plants at very low levels, if at all. Other pollutants, such as mercury, boron and arsenic can sometimes be emitted in miniscule levels, depending on the nature and make up of the geothermal reservoir. One pollutant, hydrogen sulfide, called a "nuisance pollutant" because of its rotten egg odor at very low concentrations, is of larger concern for the industry and great measures have been taken over the years to reduce H_2S emissions from geothermal facilities. For example, since 1976, hydrogen sulfide emissions have declined from 1,900 lbs/hr to less than 200 lbs/hr with the help of abatement technology, although geothermal power production has increased from 500 megawatts (MW) to well over 2,600 MW.

Another metal found in some geothermal resources is mercury. Mercury has been found in the geothermal resource at The Geysers, which was mined for mercury up through World War II. The metal vaporizes with the steam and either binds with the sulfur, if the hydrogen sulfide is abated using a chemical abatement process such as Stretford, or it is emitted as a gas. A mercury removal system was created to remove the elemental mercury from the hydrogen sulfide rendering the generated sulfur as an agriculture by-product or removing it from the plants' air emissions. Because of this, mercury emissions at The Geysers have been drastically reduced. Thus, this design improved what was already a clean, renewal resource since the air district downwind of The Geysers is the only air district in California to meet all federal and state ambient air quality standards.

LEAMS

LEAMS is one technology that can eliminate many environmental issues associated with geothermal energy development. This device would significantly reduce noise, air pollution (including particulate matter), surface contamination, and forest damage during winter months from condensed steam, secondary abatement and transient gas dispersion, and improve transient safety from blowing the unit off location during well testing. To give some specific examples, LEAMS Coso reduced the particulate carryover by 99% over BACT cyclone technology, virtually eliminating particulate emissions. At Glass Mountain, LEAMS demonstrated significant noise reduction and the ability to jet the clean steam high into the atmosphere to protect the trees from potential ice damage during the winter months.

Institutional Barriers:

Updated Resource Assessment: The United States Geological Survey performed a survey of geothermal resources in the United States in 1978, and all the exploration and resource delineation since that time has been based on this 30-year old data. Geophysical techniques as mentioned above, continual improvement in drilling costs and efficiency combined with the ability to utilize lower temperature resources lead to the need for an updated resource assessment.

Leasing/Permitting Issues: As the Subcommittee is aware, the development of geothermal resources in the United States is undermined by federal and state leasing and permitting systems that are expensive, time-consuming, and often duplicative. The House Resources Committee has adopted legislation sponsored by Representative Gibbons that would address many of the legal issues posed to new development by the out-of-date Geothermal Steam Act, and Secretary Norton is leading a continuing effort to streamline and rationalize leasing and permitting procedures in the federal agencies. We hope both will succeed.

Conclusion

Iceland is a country that relies 100% on their indigenous hydropower and geothermal energy. The Japanese have also made tremendous strides in geothermal in order to gain independence from foreign oil and are actively exporting their technology to developing nations. The Phillipines now produces 25% of its electricity from geothermal resources. We are capable of improving our use of indigenous renewable energy to improve our national security as well.

The promise of continued technological advances will not be a reality without adequate funding to support the universities and national laboratories that have the knowledge and resources to continue to make geothermal a resource that can compete with cheap fossil fuel. We need to keep in mind that when a geothermal resource is developed no fuel purchase is required unlike a coal or gas-fired power plant where the fuel is their primary operating cost, and that means that investors choosing to develop geothermal power facilities invest much more capital up-front and take on a greater risk that future energy prices will fluctuate unpredictably.

Before closing, I want to point out that the use of geothermal resources by ranchers, local governments, small businesses, and others for non-electric "direct uses" (greenhouses, aquaculture, space heating, and the like) can also provide significant indigenous energy resources for our country. As technology develops to allow more economical use of the earth's heat, it will also enable a wide range of direct use applications to flourish.

Thank you for this opportunity to testify before the Subcommittee. I am pleased to answer any questions.